available with consumer EDTV displays compared with HDTV displays.

There are no plans to do a complete "dry-run" of the test center, so there is risk that bugs will be found during, rather than before, ACTV's test period.

The bank of 24 NTSC receivers used to assess compatibility is supposed to be representative of typical product. There is no means to assure that this is so, nor is there any provision for certifying that their performance has not changed during the 1-2 years of proponent testing.

There is no means to assure that all the NTSC receivers can be recorded so that the interesting ones can be used for subjective test, nor is there means to assure that the baseband output (if provided) that will be used for recording has the same performance as the display. There is also uncertainty in the synch circuit performance of the recorders used for ATV impairment testing.

C. Identify system features claimed for ACTV that will not be included in the system submitted for test.

Pan and scan

D. Estimate the potential for interference into both NTSC and ACTV of subcarrier used in the ACTV system.

The subcarriers are separated to the point of invisibility by the ACTV receiver. Our tests of NTSC receivers with an ACTV signal input indicate minimal-to-no visibility of subcarriers.

E. **Provide a unified document describing the system submitted for test, so that references to outdated or incomplete other documentation can be avoided. This documentation should be available before actual testing begins.**

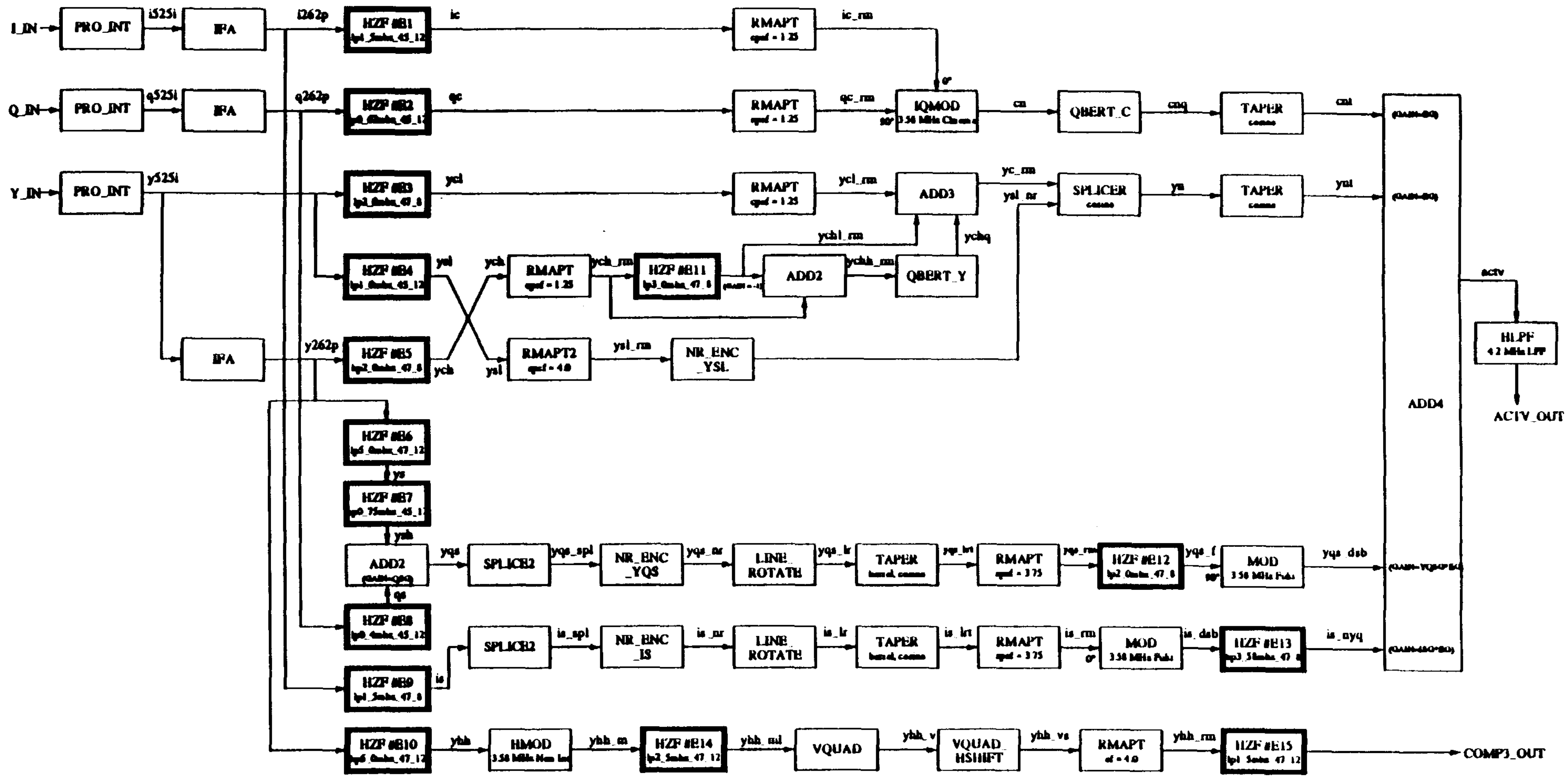

Fig. 1 Encoder

Gains:
QSG = 0.625
YQSG = 0.42
ISG = 0.35
EG = 0.9

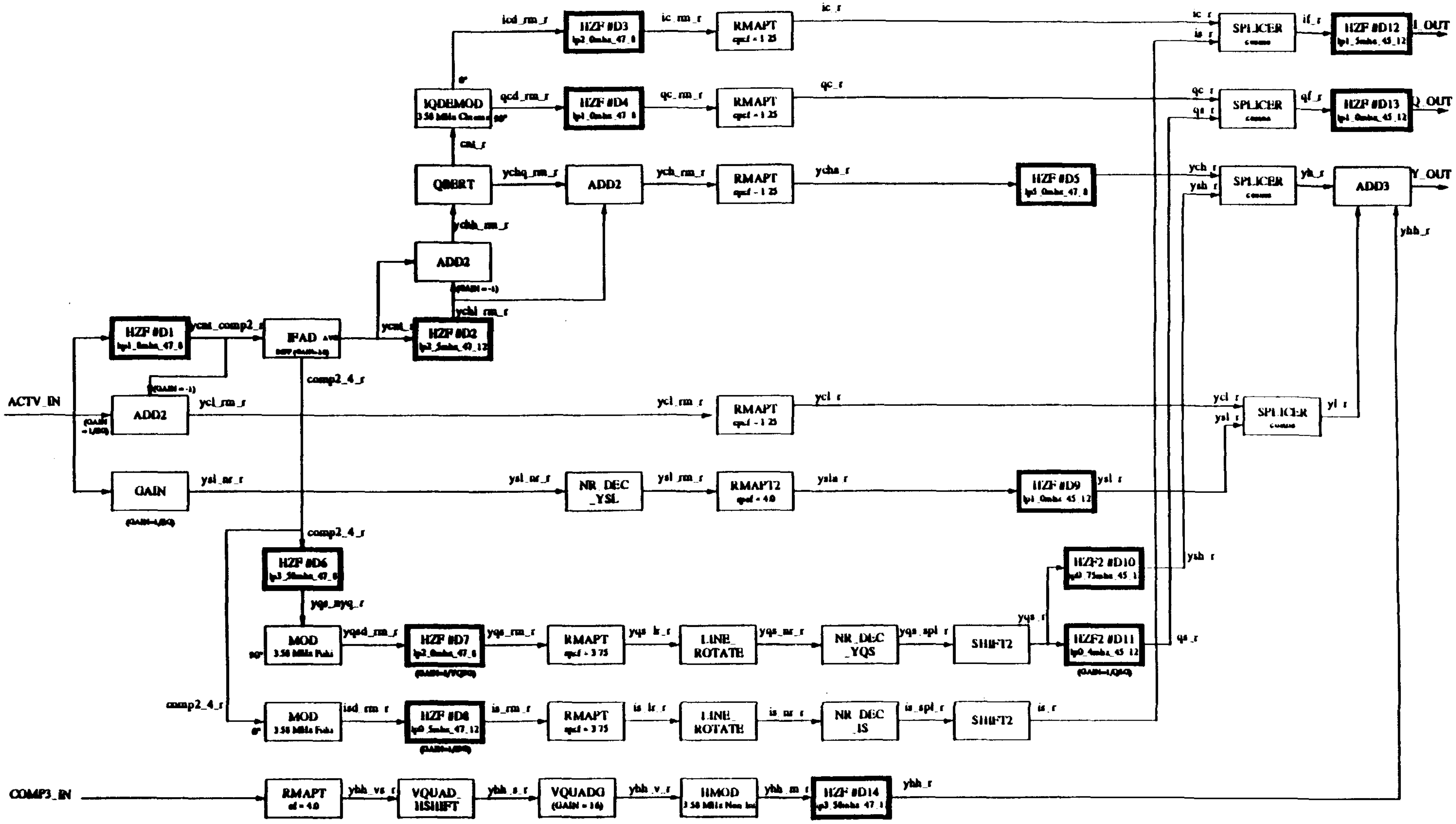

Fig. 2 Decoder

Gains:
QSG = 0.625
YQSG = 0.42
ISG = 0.35
EG = 0.9

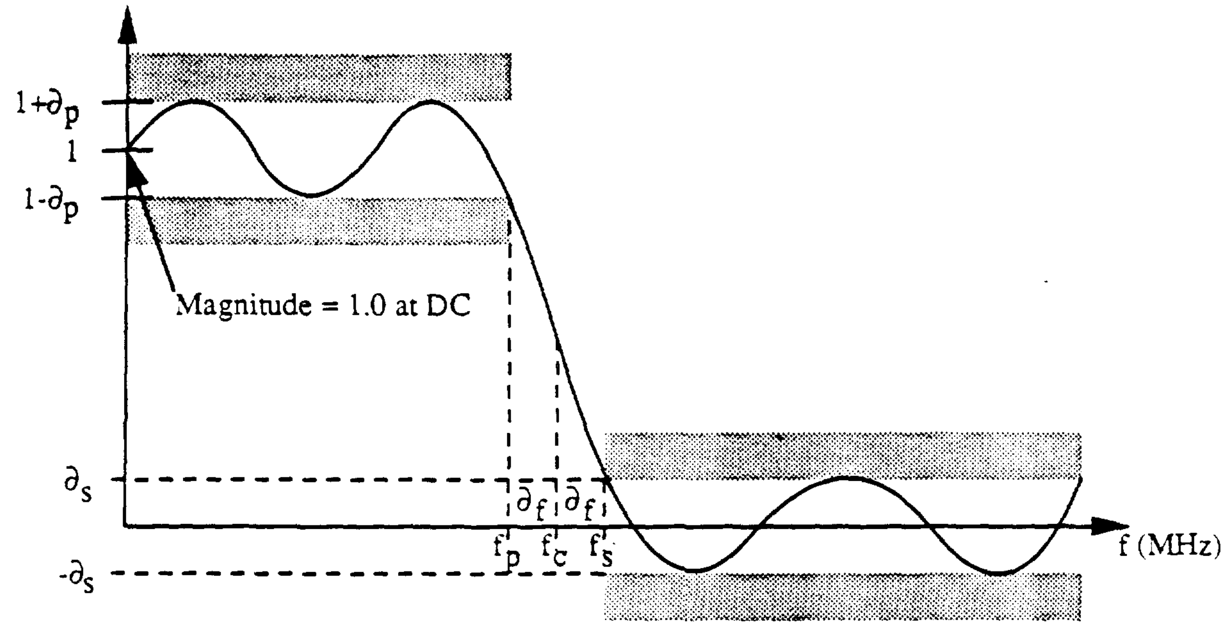

Fig. 3 Error Tolerance for Lowpass Filter Design

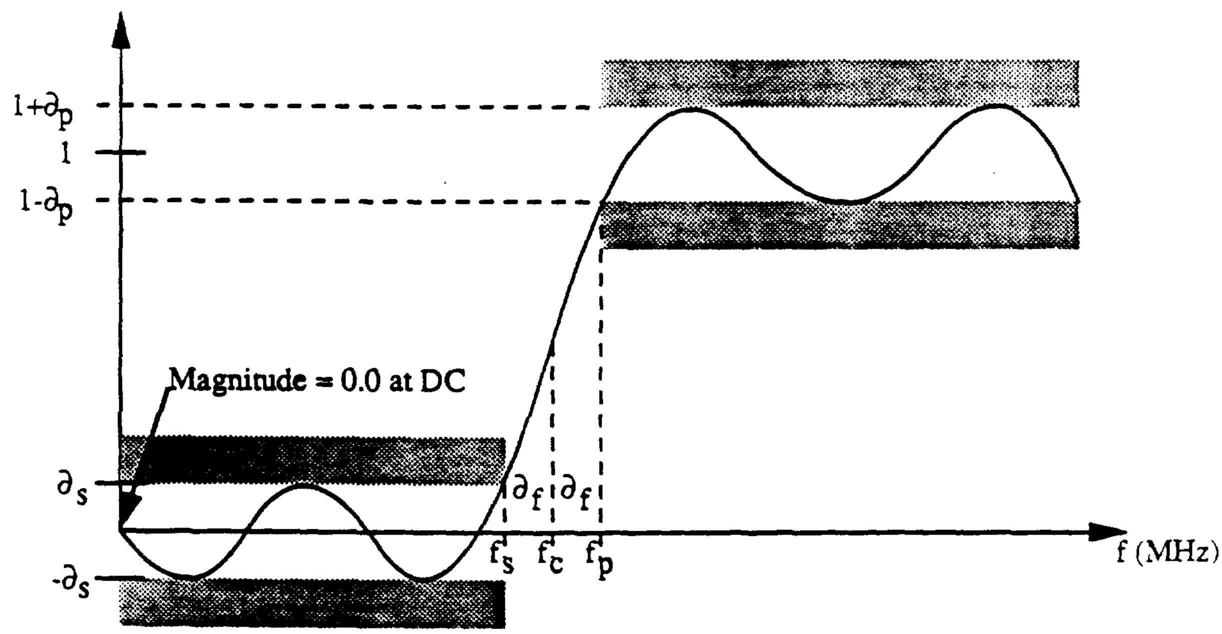

Fig. 4 Error Tolerance for Highpass Filter Design

TAILOR THE COMPANDER TO THE SIGNAL: ADAPTIVE DIRECT COMPANDING

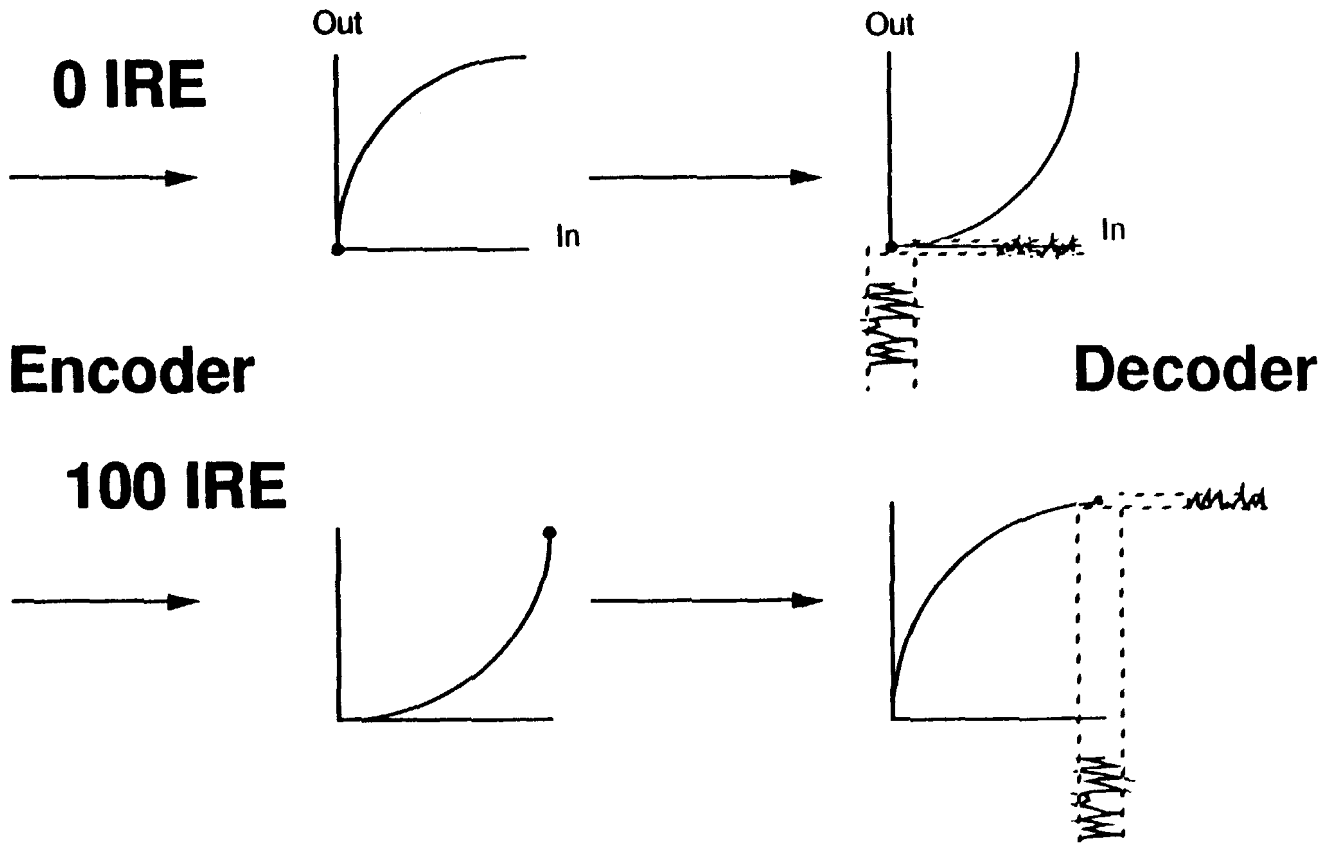

Fig. 5

A FAMILY OF COMPRESSION CURVES

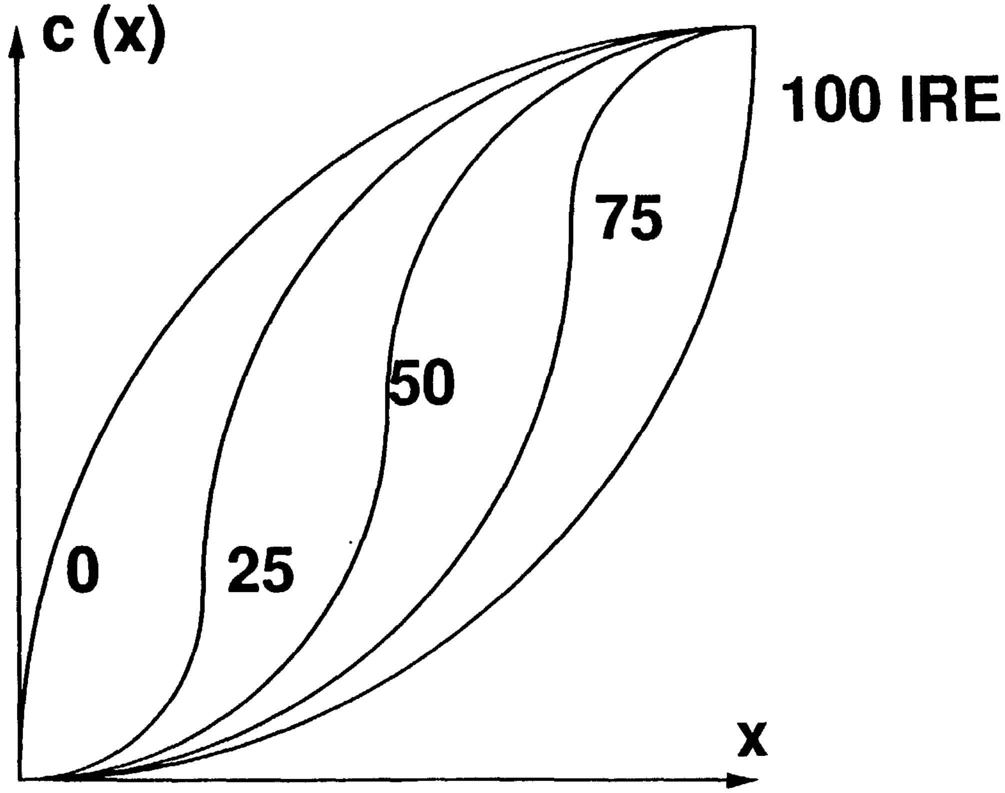

Fig. 6

COMPENSATED ADAPTIVE DIRECT COMPANDING SYSTEM

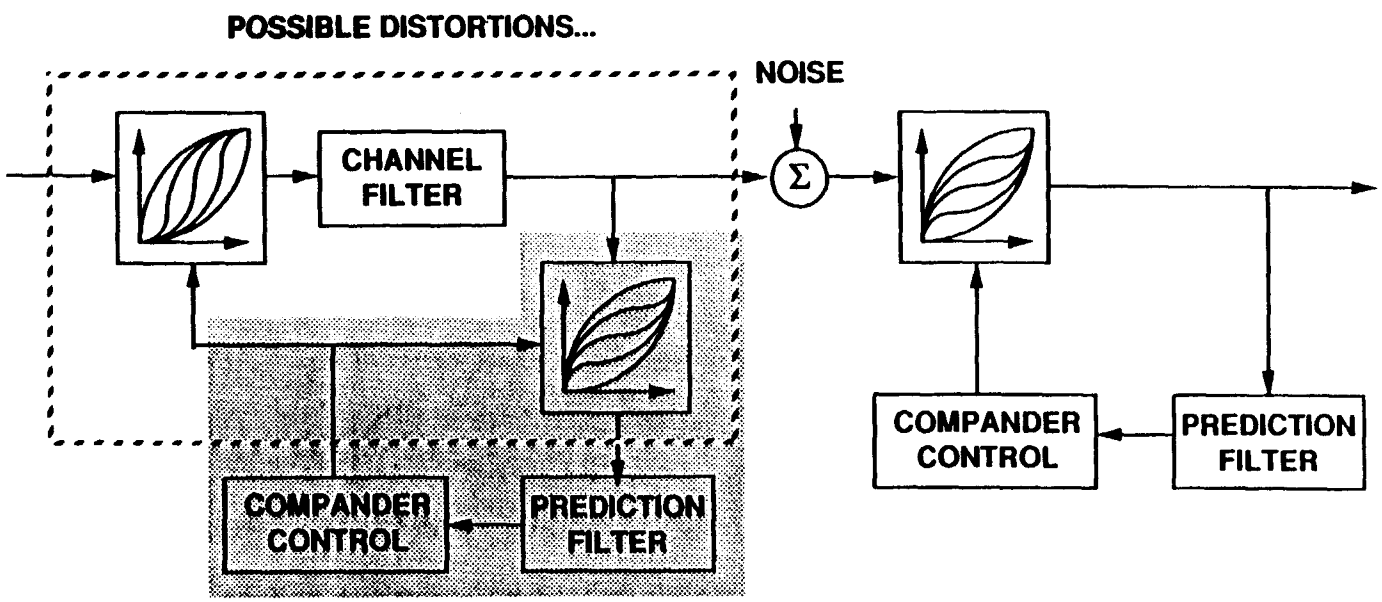

Fig. 7

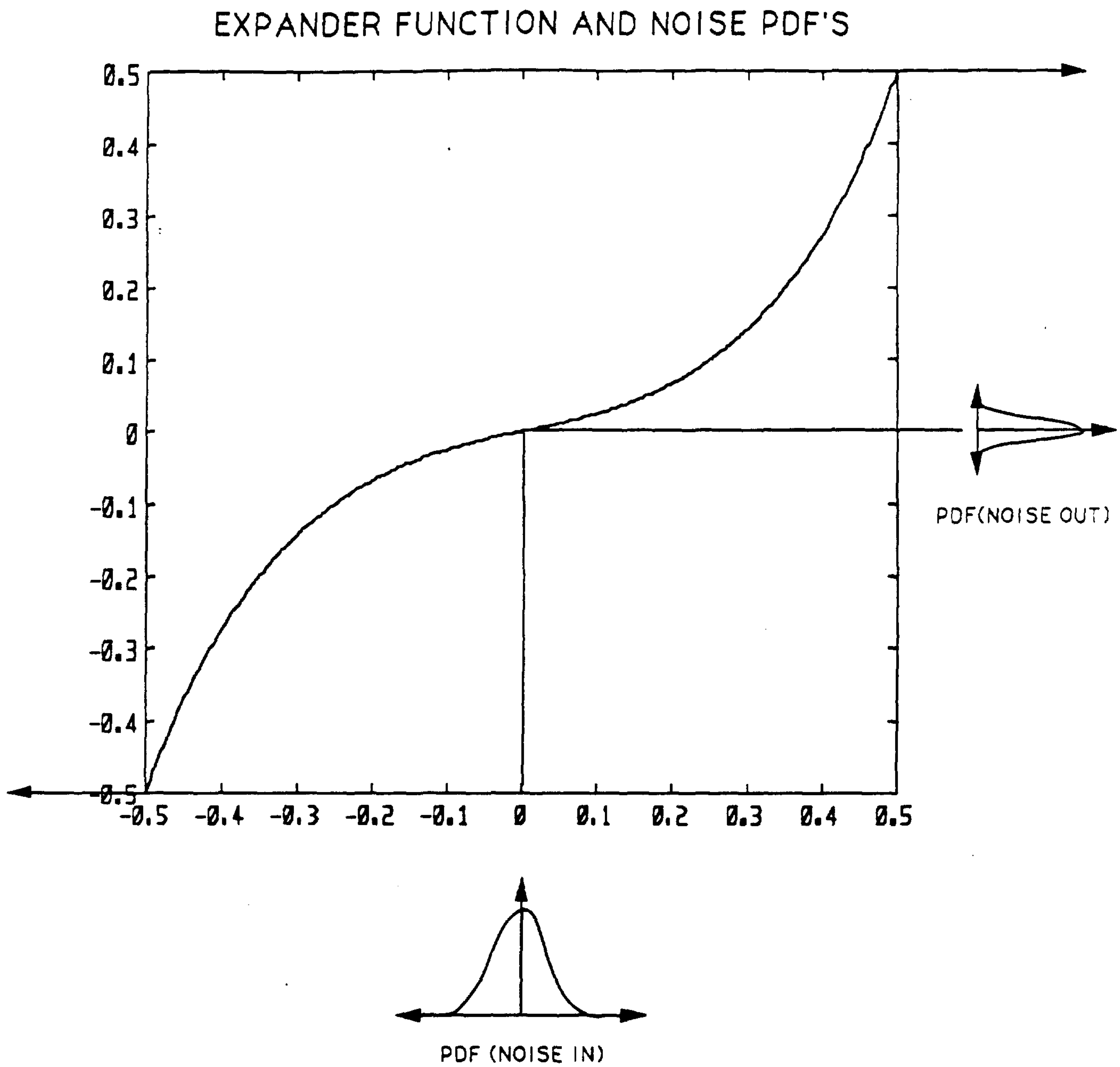
EXPANDER FUNCTION AND NOISE PDF'S
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
PDF(NOISE OUT)
PDF (NOISE IN)

Fig. 8

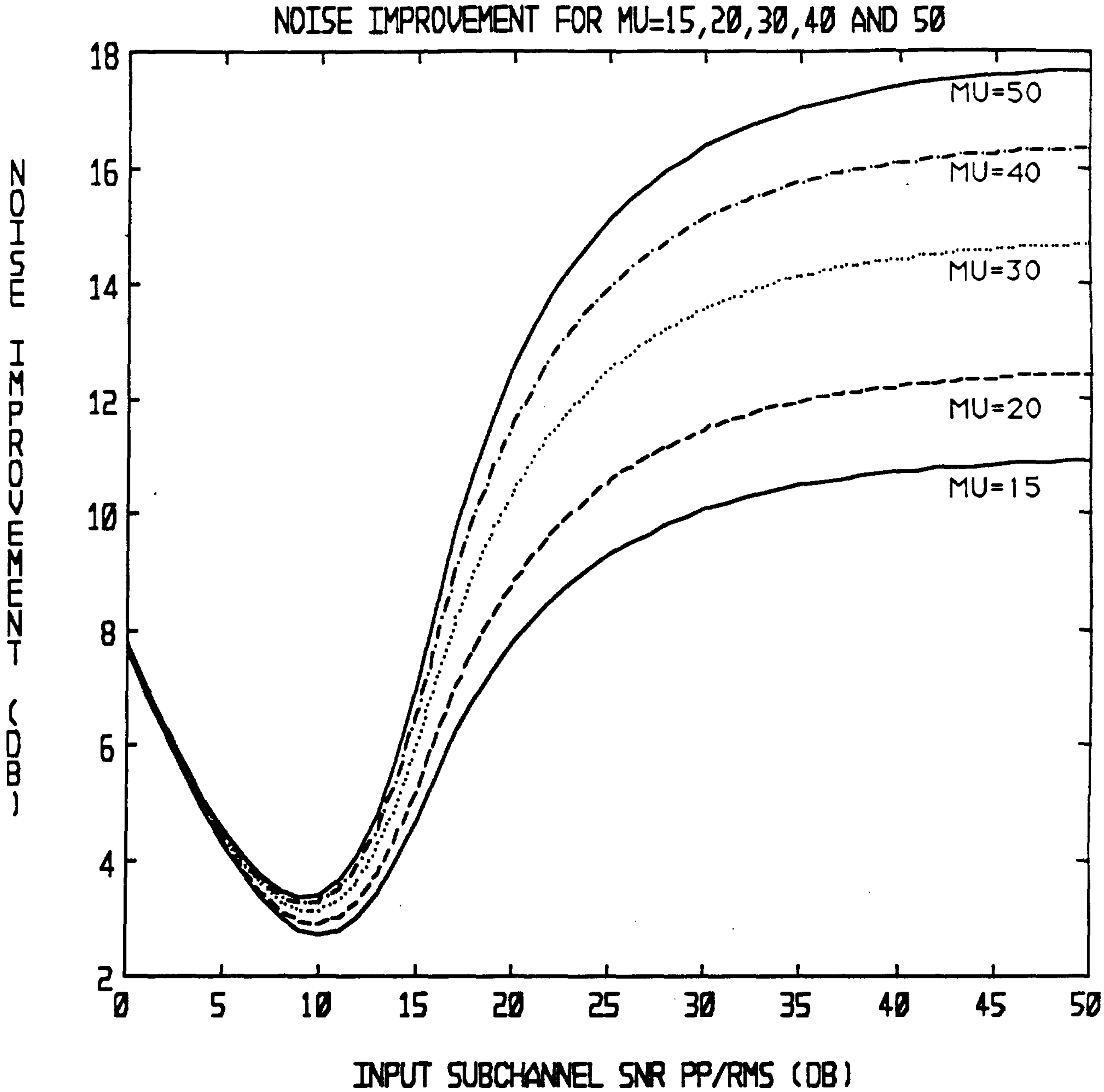
NOISE IMPROVEMENT FOR MU=15,20,30,40 AND 50
NOISE IMPROVEMENT (DB)
INPUT SUBCHANNEL SNR PP/RMS (DB)
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
40
45
50
MU=50
MU=40
MU=30
MU=20
MU=15

Fig. 9

Table 1: Horizontal Filter Specifications

Filter #	Type	*fc (MHz)*	∂f (MHz)	∂p	∂s	DC Gain
Encoder						
E1	lowpass	***1.50***	0.30	0.05	0.05	1.00
E2	lowpass	***0.62***	0.20	0.05	0.05	1.00
E3	lowpass	***2.00***	0.30	0.05	0.05	1.00
E4	lowpass	***1.00***	0.20	0.05	0.05	1.00
E5	highpass	***2.00***	0.30	0.05	0.05	0.00
E6	lowpass	***5.00***	0.30	0.05	0.05	1.00
E7	highpass	***0.75***	0.20	0.05	0.05	0.00
E8	lowpass	***0.40***	0.20	0.05	0.05	1.00
E9	lowpass	***1.50***	0.30	0.05	0.05	1.00
E10	highpass	***5.00***	0.30	0.05	0.05	0.00
E11	lowpass	***3.00***	0.30	0.05	0.05	1.00
E12	lowpass	***2.00***	0.30	0.05	0.05	1.00
E13	"highpass"	***3.58***	0.50	0.05	0.01	0.00
E14	lowpass	***2.50***	0.30	0.05	0.05	1.00
E15	lowpass	***1.50***	0.30	0.05	0.05	1.00
Decoder						
D1	highpass	***1.80***	0.30	0.05	0.05	0.00
D2	lowpass	***2.50***	0.30	0.05	0.05	1.00
D3	lowpass	***3.00***	1.00	0.05	0.05	2.00
D4	lowpass	***0.50***	0.30	0.05	0.05	2.00
D5	lowpass	***5.50***	0.30	0.05	0.05	1.00
D6	"lowpass"	***3.58***	0.50	0.05	0.05	1.00
D7	lowpass	***2.00***	0.30	0.05	0.05	2.38
D8	lowpass	***0.50***	0.30	0.05	0.05	2.86
D9	lowpass	***1.00***	0.20	0.05	0.05	1.00
D10	highpass	***0.75***	0.20	0.05	0.05	0.00
D11	lowpass	***0.40***	0.20	0.05	0.05	1.60
D12	lowpass	***1.50***	0.50	0.05	0.10	1.00
D13	lowpass	***0.58***	0.30	0.05	0.10	1.00
D14	highpass	***4.30***	0.40	0.05	0.05	0.00

APPENDIX C

ISSUES FOR CLARIFICATION

AND FURTHER

RECOMMENDATIONS FOR

SYSTEM-SPECIFIC TESTS

Appendix C

ISSUES FOR CLARIFICATION

and FURTHER RECOMMENDATIONS FOR SYSTEM-SPECIFIC TESTS

ISSUES FOR CLARIFICATION

The Analysis Task Force in Working Party 1 has carefully considered the technical documentation supporting the ACTV system proposed by the David Sarnoff Research Center. The Task Force believes the following items need clarification, although they are not of sufficient importance to prevent final certification.

1. The relative amplitude of the Fukinuki subcarrier (Component 2) should be specified. It would be preferable if the proponent were to specify a method of measurement as well as expected levels.
2. The pseudo-random sequence of length 255 sent as a reference signal is repeated 3 times, according to page 10 of the Jan. 7, 1991 document from Sarnoff. A diagram or further explanation is needed to understand the placement of the signal in the lines of the vertical interval. The line number will be the lowest active video line in the equipment to be tested, and the testing laboratories need to be alerted to that location of the reference signal. Further clarification of the expected rate of convergence of the ghost canceling sub-system is desirable.
3. The descriptive document of Jan 7, 1991 leaves open the type of display to be used in the tests for ACTV (whether 525 progressive or 1050 interlaced). The display format needs to be unambiguously established and made known to all parties.
4. On page 7 of the Jan. 7 document, it was unclear from the explanation given how the 2x6 field-varying V-T filter used for vertical-temporal filtering operates, especially in performing the intraframe averaging.
5. As with Component 2, the proponent should indicate a method for measuring the carrier level for Component 3, with expected levels.
6. We note that the pan-and-scan feature described in the January 7 document is not included in the items to be tested, according to agreements at the November 5, 1990 meeting of Working Party 1.

FURTHER RECOMMENDATIONS FOR SYSTEM-SPECIFIC TESTS FOR THE ACTV SYSTEM

The Analysis Task Force has continued its analysis of the ACTV system, and proposes the items in the following list as potential subjects of system-specific tests, in addition to the recommendations for system-specific tests contained in the draft report.

1. Fukinuki carrier level: if information is provided by Sarnoff indicating an appropriate method of setting relative power level of the Fukinuki subcarrier, the method should be implemented and the levels documented.

2. Power level for Component 3: information of the power level and measurement method from Sarnoff should be implemented and the levels documented for the relative power level of the quadrature modulated Component 3 relative to the main picture carrier level.

3. The behavior of digital audio as signal strength varies should be observed. In particular, the signal levels at which a transition from digital audio to intercarrier audio (and the reverse transition) should be noted. Although it is a receiver implementation issue, it may be of interest to observe the character of the transition to see if it is a smooth transition or objectionable, while documenting the associated levels. Additionally, the acquisition time for recovery to digital sound could be observed, to see if it is noticeable.

4. The performance of the FM intercarrier sound channel is assumed to be unaffected by the new signals introduced in ACTV. The FM audio performance could also be measured to verify that assumption.

5. Ghost canceling: performance as a function of noise. Since ghost canceling circuits may have their performance degraded by additive noise, including both the ability to identify small ghosts and the time to cancel them, we recommend observations of the ghost canceling performance with several power levels for desired signal, and with both weak and strong ghosts. Desired power levels of -15 dBm, -35 dBm, and -55 dBm have been suggested as providing an adequate range of S/N ratios.

6. Ghost interference from side-panel information: we recommend a test with a relatively strong multipath component having a delay greater than 5 micro-seconds. The purpose is to examine the potential for side-panel information sent in the overscan region becoming visible in the main picture area of a typical NTSC receiver.

7. Smearing of moving edges could result from the operation of noise-reducing circuits and motion-adaptive scan conversion. Although the general testing procedures may be adequate for examining such effects, observations that attempt to relate such effects to the ACTV processing may prove useful.

8. Conditional access: the ACTV signal should be sent through typical conditional access equipment to determine the effect on both NTSC receivers receiving such an ACTV signal and on an ACTV receiver with such an input.

9. Set-top converters: the ACTV signal should be sent through typical set-top converter boxes to both NTSC and ACTV receivers.

   The pictures should be scrutinized particularly for evidence of visible Component 2 elements.

APPENDIX D

SYSTEM DESCRIPTION

SUBMITTED BY PROPONENT

to ACATS SS-WP1

System Description

ADVANCED COMPATIBLE TELEVISION

Submitted by

David Sarnoff Research Center, Inc.

CN 5300
Princeton, N.J. 08543-5300

January 7, 1991

Table of Contents:

EXECUTIVE SUMMARY

Advanced Compatible Television (ACTV) offers enhanced definition, wide aspect ratio, and digital audio while fitting compatibly within a standard 6-MHz NTSC channel. ACTV is compatible with all existing NTSC receivers. When ACTV is transmitted, NTSC receivers will display a normal (4x3) aspect ratio, NTSC-quality picture virtually indistinguishable from their present performance; ACTV receivers will display a 16x9 aspect ratio image, a horizontal resolution improvement of about 30% over NTSC, and progressive scanning. In order to include this increased information within the same TV channel bandwidth, a new video subcarrier has been introduced, the low-frequency content of the edges of the wider picture has been compressed into the receiver's horizontal overscan region, and the picture carrier has been quadrature-modulated with additional detail information. Digital audio is modulated onto a new carrier located in the vestigial sideband portion of the compatible transmission.

ACTV is consistent with display technologies anticipated for the future, and it can be delivered without new channel allocations.

This document describes the ACTV hardware that will be delivered for test by the ATTC in April 1991. It includes relevant information from and in some instances supercedes earlier system descriptions submitted on September 1, 1988 [13], November 14-18, 1988 [32], December 31, 1989 [33], and November 5, 1990 [34].

DESCRIPTION OF THE ACTV SYSTEM

SUMMARY OF ACTV

ACTV features 16x9 widescreen aspect ratio, wideband I, increased horizontal luminance resolution compared with NTSC, unassisted progressive scan conversion in the receiver, and pan-and-scan capability.

The ACTV video signal is fully compatible when decoded by existing NTSC receivers. The transmitted ACTV signal consists of a main signal plus an auxiliary horizontal detail signal sent in RF quadrature. The main signal contains the NTSC encoded 4x3 center panel plus additional side panel information. Existing NTSC receivers decode the main signal as a normal color picture; the side panel and auxiliary detail signals are physically or perceptually hidden from view. All signals are recovered by an ACTV receiver to reconstruct a widescreen EDTV image.

OVERVIEW OF THE ACTV SIGNAL COMPONENTS & SUBCHANNELS

ACTV has three separate video signal components, as will be described below. The new components are carried in "subchannels" within the NTSC spectrum. The subchannels themselves are described in the section on Modulation Techniques. ACTV matches the subchannel characteristics to the requirements of the information the subchannels carry.

Figure 1 shows a block diagram of the video portion of the ACTV system.

ACTV Signal Source and Display

ACTV images are derived from a 525-line progressively scanned source (525/1:1). 1050-line interlaced and 525-line interlaced sources are also possible, but are not preferred. The images are converted to 525-line interlaced signals (525/2:1) for compatible transmission. The display is 525/1:1. An alternative 1050/2:1 display format may be required for test purposes only (not consumer product) if the laboratory test monitor is not suited for 525-line rendition.

Component 1: The "Main" Signal

The 525/1:1 widescreen source is converted to 525/2:1 by the encoder. These 525/2:1 interlaced YIQ signals (in 16x9 aspect ratio) are converted to standard 4x3 aspect ratio. Because the widescreen camera has effectively scanned a greater angular distance in the same amount of time, the horizontal bandwidth is proportionately increased. The aspect ratio conversion is shown pictorially in Figure 2.

As a first step in the conversion process, the central 4x3 portion of each wide screen line is time expanded to fill all but 3 microseconds of the entire active line time of the compatible signal. Time expansion causes a drop in bandwidth, and so the wide screen luma and chroma signals can now fit into standard NTSC bandwidths.

The side panel luminance signals are separated into two horizontal frequency bands, the "lows" and the "highs", which are processed differently. 1.5 microseconds on each edge of the active line is reserved for a time-compressed rendition of the side panel luminance low frequencies. These compressed low frequencies, which contain the DC component of the luminance and most of the signal energy in the side panels, are hidden by the normal horizontal overscan in standard home receivers. The compression factor for the side panel low frequencies is four. To fit into the standard NTSC bandwidths, the cutoff frequency for the compressed side panel luminance is 1 MHz.

The resulting YIQ signals contain both the central 4x3 portion of the wide screen image and the side panel low frequencies compressed into the left and right overscan regions. These signals have standard NTSC horizontal bandwidths. In the main channel, luma high frequencies and chroma are prefiltered by an adaptive line comb, thereby reducing luma/chroma crosstalk at the transmitter. In the ACTV receiver, an adaptive line comb decoder is used to separate luma highs from chroma virtually free from crosstalk. Even conventional (i.e., NTSC) notch and line-comb receivers will exhibit reduced chroma/luma crosstalk from this prefiltering. The resulting composite signal, called the Main NTSC Signal, is shown as Component 1 in Figure 2.

The visibility of the seam between side and center panels is minimized in three ways: 1) by sending the low-frequency components as part of the main signal, which makes the matching of the DC level inherent; 2) by transmitting redundant pixel information to assist panel seaming; and 3) by introducing pixel "guardband" regions to reduce ringing at the panel edges. At the encoder, the center panel actually overlaps the side panel such that several video samples are effectively transmitted twice. When this redundant information is recovered, the overlap region allows a mixing of the center and side panel information, creating a feathered seam instead of a hard transition. Transient effects at the panel seam are effectively eliminated.

Component 2: Side Panel Luma High Frequencies & Side Panel Chroma

Component 2 contains the luminance frequencies that are not compressed into the overscan region (the range from 1 MHz - 5 MHz) and the entire side panel chrominance. These signals are time expanded by a factor of 3.75 to fill the portion of the active line time occupied by the center panel. The time expansion causes a drop in overall bandwidth to about 1.5 MHz. The resulting signal is shown as Component 2 in Figure 2. The time expanded side panel high frequencies are spatially uncorrelated with the main signal, and special precautions, to be discussed later, must be taken to mask their visibility on standard NTSC receivers.

The method by which these signals are modulated will be described later.

Component 3: Extra Horizontal Luminance Detail

Components 1 and 2 carry about 4.5 MHz of horizontal luminance information from the transmitted 525/2:1 interlaced widescreen signal. To provide extended horizontal resolution, the luminance detail in the range 4.5 - 6.5 MHz is time expanded 4:1 to reduce its frequency range and down-converted for transmission in RF quadrature. The baseband signal is shown as Component 3 in Figure 2.

Modulation Techniques and Compatibility

The ACTV signal components discussed above are combined into a compatible NTSC signal and transmitted over a single 6-MHz RF channel. To achieve compatibility, the ACTV system uses the following techniques to hide the extra components. Each of these techniques may be considered to have opened a new "subchannel" within the NTSC signal or its spectrum.

> The high-energy side panel luminance low frequencies are physically hidden in the normal horizontal overscan of existing NTSC receivers.

The various signals of Component 2 are randomly line-rotated, combined and quadrature modulated onto a new subcarrier at 3.579545 MHz. This is exactly the same horizontal frequency as the NTSC color subcarrier, but the phase is inverted on alternate fields. Although the modulated components reside entirely within the chroma band (2.0 - 4.2 MHz), they are perceptually hidden because they are displayed as 30-Hz complementary-color flicker, which is not perceived by the human visual system.

Component 3, the extra horizontal luminance resolution, is sent in a 230-750 KHz band, quadrature modulating the RF picture carrier.

The side panel luma high frequencies and chroma that are sent on the alternate subcarrier may be adjusted in level to match the spatial and temporal responses of both the camera and the display. If broadcasters elect this option, both large amplitude high frequency luma signals and chroma saturation will be amplitude-tapered toward the edges of the image. This reduces the level of the alternate subcarrier and improves compatibility. The tapering function is not constant or even linear with signal level; low-level detail and sensitive pastel colors are sent full amplitude. The tapering is coded in ROM and is a function of both spatial position and signal amplitude. The subjective effect of this operation matches well the image rendition of consumer picture tubes. The ACTV hardware to be delivered for test will include such taper functions. The receiver hardware performs an inverse of the tapering function under conditions of good recovered S/N.

Intraframe Averaging and Differencing

To achieve recoverability of Components 1, 2, and 3, a novel process called *intraframe averaging* (IFA) was developed. Intraframe averaging [2], [3], [8], [13] is a linear, time-varying digital filtering technique that can separate a modulated signal from a baseband signal free from vertical-temporal crosstalk, even in the presence of motion. Horizontal crosstalk is eliminated by frequency guardbands between horizontal pre- and post-filters.

The intraframe averaging method is shown in Figure 3. Pairs of pixels 262H (one field) apart *within an interlaced frame* are averaged, and the average value replaces the original pixel values. This vertical-temporal averaging occurs only within a frame and does not cross frame boundaries. In Component 1, intraframe averaging is performed only on luminance frequencies above 2 MHz. (This averaging may be performed on a *composite* signal throughout the entire chroma band; the composite signal survives intraframe averaging because pixels 262H apart are "in-phase" with respect to the color subcarrier, i.e., the IFA'd signals have the same information content as 262-progressive signals.) ACTV's hardware, as shown in Figure 4 intraframe averages in the "Unified Front End", creating all 262-progressive signals in component form. The essential point is that signals that are IFA'd have pairs of identical fields within a frame.

The phase of the new, alternate subcarrier is controlled so that it is exactly out of phase for pixels 262H apart. Therefore, when Component 2 is quadrature modulated and added to Component 1, pixels 262H apart have the form (M+A) and (M-A), where M is a sample of the main composite signal above 2 MHz, and A is a sample of the auxiliary modulated signal.

Receiver circuits take the average and difference of pixels 262H apart within a frame to separate completely the main samples from the auxiliary samples. With intraframe averaging, vertical-temporal crosstalk is exactly eliminated, even in the presence of motion. Furthermore, it is achieved using a *single frame store*, which is in contrast to linear time-invariant methods that require several frame stores to produce similar results.

Intraframe Averaging halves the temporal update rate of the IFA'd frequencies. Thus, in the center panel, horizontal frequencies above 2 MHz are sent at a 30 Hz rate. As is well known, the effect of reducing the temporal rate of frequencies this high is quite benign. However, the corresponding IFA frequency for the side panels (with high frequencies sent on the alternate subcarrier) is 1 MHz. The difference between these frequencies means that a small amount of jerky motion, called "judder", could become visible in the side panels. To remove the side panel judder and to make side panel motion rendition match that of the center panel, ACTV sends a "side panel luma difference" (YSD) signal as part of Component 2.

The YSD signal is derived by recovering the Intraframe Difference (IFD) signal between 1 and 2 MHz. The IFD is obtained by subtracting the IFA'd signal from the interlaced input. The YSD signal is added to the narrowband side panel I (IS) signal in the same way that luma side highs (YSH) are added to the side panel Q (QS) signal (the technique will be described later). In the receiver, the YSH and YSD signals are combined to restore full V-T resolution for the side panels in the 1-2 MHz range.

ACTV ENCODING

Encoding is described in Figures 1 and 2. The original RGB 16x9 source signals are digitized, converted to YIQ, prefiltered in V-T and subsampled to 525-line interlaced format. These interlaced signals are further preprocessed and decomposed into the three components discussed above: Component 1, the NTSC encoded expanded center panel plus the compressed side panel luma lows; Component 2, the side panel luma highs, side panel luma differential judder elimination, and side panel chroma; and Component 3, additional horizontal luminance detail for the entire image. Components 1 and 2 are combined to form the Main ACTV Signal, which is sent on one phase of the RF carrier. Component 3's luma highs are modulated into the range 230 KHz - 750 KHz and are sent in RF quadrature with the main signal.

Encoder Preprocessing

The encoder accepts widescreen YIQ inputs with a field rate of 59.94 Hz. The preferred format is 525-line progressive (525/1:1), but 1050-line interlaced (1050/2:1), and 525-line interlaced (525/2:1) are possible. A low-cost entry-level system could use readily available 525/2:1 widescreen source material and could be upgraded by switching to 525/1:1 source material.

The unified V-T "front-end" accepts any of these input formats, and produces a single 525/2:1 format as output. 1050/2:1 or 525/1:1 inputs are sampled at FS = 16xFSC = 57.2 MHz, where FSC = 3.579545 MHz; 525/2:1 inputs are sampled at FS = 8xFSC = 28.6 MHz. The digitized signals are digitally lowpass filtered to FS/4, and then resampled at FS/2. The signals are then prefiltered in the vertical-temporal (V-T) dimensions using a field-varying 8-line x 5-field V-T FIR lowpass filter. This field-varying filter serves both to bandlimit and intraframe average (IFA) the signals. In practice, a 3x3 V-T linear time invariant filter is sufficient to band-limit the luma lows, and a 2x6 field-varying V-T filter is sufficient to band-limit the IFA'd signals (luma highs and chroma). If a 525/1:1 or 1050/2:1 source is used, the filtered signals are then subsampled to interlace format. As an example, Figure 3 illustrates the preprocessing that is performed for 525/2:1 inputs.

The intraframe averaged luma signal is bandsplit by a 5 MHz horizontal filter (ACTV's filters are described in Appendix A) into low and high frequencies. The horizontal highs signal, YHH (also called Component 3) is processed as described in more detail below. The four other outputs of the preprocessor are the Intraframe Averaged Y, I, and Q signals and the interlaced Y signal. These four signals then pass through a bank of horizontal filters, producing the signals, I, Q, YCL (Y center lows), YSL (Y side lows), YCH (Y center highs), YSH (Y side highs), and YSD (side panel Y difference).

The "unified front end" derives the YSD signal by subtracting the Intraframe Average (IFA) signal from the input. Alternate fields must then be reversed in polarity so that pairs of fields are identical; if pairs of lines a field apart are of the form (A+B)/2 in the IFA signal, then they are of the form (A-B)/2 in the YSD signal. Over the frequency range between 1 and 2 MHz, this YSD signal supplies side panel difference information. The YSD signal is added to the I component of chrominance for the side panel (which is narrowband in the side panel) and modulated with the other Component 2 signals onto the alternate subcarrier. The result is restoration of full V-T resolution in the side panels up to horizontal frequencies of 2 MHz, which matches the center panel.

Component 1 Encoding

As shown in Figure 4, the center panel signals IC, QC, YCL, and YCH are horizontally expanded by a factor of 1.25. The process of horizontal expansion and compression is performed by *raster mapping*, which will be described later. There is no geometric distortion on the ACTV image; the image displayed on NTSC receivers would have a geometric distortion of about -5% (i.e., objects appear 5% thinner), which is comparable to the distortions in existing NTSC display systems. The center panel chroma signals are modulated by the standard NTSC color subcarrier (FSC = 3.579545 MHz, interlaced). The modulated chroma signal then passes through an adaptive line pre-comb to remove chroma components that would appear as luma. The edges of the modulated chroma panel are tapered to prevent ringing through the narrow chroma channel. Tapering provides pixel guardbands to eliminate the ringing that would otherwise occur when the signal is passed through a band-limited channel; it will be described in detail later. The expanded center panel luma highs are passed through an adaptive line pre-comb to remove luma components that would appear as modulated chroma. The center panel luma lows are then added to the center panel luma highs. The side panel luma lows (1 MHz bandwidth) are horizontally compressed into the overscan regions by a factor of 4, and are then processed by a noise reduction module. The noise reduction processing is described later. The overscan regions are 1.5 microseconds wide on each edge of the picture. The expanded center panel and compressed overscan regions are spliced together, and guardbands are